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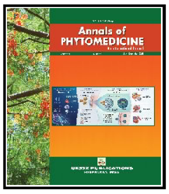

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Intercorrelation of phytonutrients with psychometric and clinical scores of native and migrant populations of Punjab, India

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Abstract

The present study examined the interrelationship between phytonutrient intake and anthropometric, biochemical, physiological, and psychometric parameters among native and migrant populations of Punjab, India. A comparative cross-sectional study was conducted among 1,585 adults aged 29 to 61 years, categorized as natives n = 858, recent migrants <3 years; n = 133 and long-term migrants = 6 years; n = 598. Dietary intake was assessed using a multiple-pass 24 h recall and a semi-quantitative food frequency questionnaire, while body composition, biochemical, and psychological parameters were evaluated using standardized protocols. No significant differences were observed in total phytonutrient intake, including dietary fiber, ascorbic acid, β-carotene, vitamin D, omega-3, and omega-6 fatty acids among the groups (p>0.05). However, dietary diversity differed significantly (F=5.251; p=0.005),with recent migrants showing the highest diversity score, 9.62 ± 1.45. Natives exhibited higher BMI 27.55 ± 4.76 kg/m², waist circumference 97.74 ± 9.96 cm, and visceral fat rating 11.68 ± 4.91; p<0.001, indicating greater susceptibility to central obesity. Blood pressure levels were also significantly higher among natives (p<0.05). Psychometric assessment revealed elevated anxiety scores in natives 4.93 ± 4.66; p=0.002, though depression and stress did not differ (p>0.05). Dietary diversity was inversely correlated with BMI, waist, and hip circumferences p<0.01 and positively associated with total body water, while β-carotene correlated positively with anxiety and stress. These findings suggest that dietary diversity, rather than individual phytonutrient intake, is pivotal for maintaining metabolic and psychological health among populations undergoing dietary transitions in Punjab.

1. Introduction

Plants naturally contain bioactive substances called phytonutrients, which are increasingly recognized as essential components of human health. Polyphenols, carotenoids, flavonoids, and glucosinolates are examples of phytonutrients that in contrast to macronutrients and micronutrients, provide protective effects through a variety of mechanisms such as antioxidant activity, modulation of inflammatory pathways and regulation of gene expression linked to metabolic and neurological functions (Liu, 2013; Rudrapal *et al*., 2022). These compounds are obtained from a diet rich in fruits and vegetables, legumes,whole grainsand spices, which has also been linked to a lower risk of cardiovascular disease, neurodegenerative diseases and metabolic syndromes (Ganpule *et al.,* 2023; Godos *et al.,* 2020; Faaz Bin Razi *et al.,* 2025; Patra *et al.,* 2015; Sun *et al.,* 2021).

There is growing evidence that the advantages of phytonutrients go beyond physical health to encompass mental health. A diet high in foods high in phytonutrients has been associated with better mood, a decreased risk of anxiety, depression,and improved cognitive function (Grazek *et al*., 2022; Lassale *et al*., 2019). The compound's capacity to improve neurotransmitter balance, mitigate oxidative and inflammatory stress in neural tissues, and favorably affect the gut-brain axis is believed to be the cause of these effects (Nicolucci *et al*., 2024). According to Panche *et al*. (2016), flavonoids, for instance,are known to enhance cerebral blood flow and neuronal signaling, supporting psychological stability and brain plasticity.

The degree of phytonutrient consumption and related health outcomes may be influenced by the different dietary and lifestyle habits of the native and migrant populations in areas like Punjab. Migration frequently causes dietary acculturation in which calorie-dense and nutrient-poor foods gradually replace traditional plant-based diets high in lentils, vegetables, and locally grown produce (Schulze *et al*., 2018). Rising rates of obesity (Ahmed and Mohammed, 2025), hypertension (Sebastian *et al*., 2022), and diabetes are often associated with this transition, especially among migrants who encounter new social and professional demands (Misra *et al*., 2021). Additionally, the psychological toll of migration, such as being cut off from social networks, experiencing stress related to adaptation, and facing economic uncertainty, can make people more susceptible to mental health issues (Bhugra and Becker, 2005).

Punjab's population structure, comprising both long-term residents and various migrant groups, creates an ideal setting to study these dietary changes. By examining how different populations adapt to this obesity promoting environment, researchers can better

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understand the factors driving metabolic disease. This study explores the relationships between diet, psychological well-being, and metabolic health across these population groups. We hypothesize that longer exposure to Punjab's modern food environment correlates with declining dietary quality, increased stress levels, and poorer metabolic health outcomes, which could inform future phytonutrient interventions.

2. Materials and Methods

2.1 Study design and ethical clearance

This investigation was executed as a robust, comparative cross-sectional epidemiological study. The research was based at the outpatient clinics of the Hero Heart Dayanand Medical College and Hospital in Ludhiana, providing access to a diverse patient and community population. The entire study protocol was developed in strict accordance with the Declaration of Helsinki and received full ethical clearance from the Institutional Ethics Committee (IEC) of DMCH, Ludhiana. Ethical approval was granted under Reference No. DMCH/IEC/2024/387. A meticulous informed consent process was undertaken, ensuring that every participant fully understood the study's objectives, procedures, potential risks, and benefits before providing voluntary written consent.

2.2 Participant recruitment and stratification

A total of 1,589 adult participants aged 29 to 61 years were enrolled in the study through a systematic recruitment process (Figure 1), but four were excluded as they were physically or mentally disabled. Participants were stratified into three residential categories to enable temporal assessment of environmental exposure. (i) Natives of Punjab: The native group comprised individuals born and permanently residing within the state of Punjab. (ii) Recent migrants: The recent migrant group included individuals who had migrated to Punjab from other Indian states and had resided there for less than three years, representing the early phase of environmental adaptation. (iii) Long-term migrants: The long-term migrant group consisted of individuals with a residence duration of six years or more, reflecting substantial adaptation to local dietary and lifestyle patterns. The migrant participants primarily originated from the states of Uttar Pradesh, Bihar, Himachal Pradesh, and Haryana.

2.3 Phytonutrient intake and dietary analysis

It was meticulously quantified using the gold standard, multiple-pass 24 h dietary recall method conducted on three non-consecutive days (including one weekend day) to capture habitual intake. This was supplemented with a culturally validated, semi-quantitative food frequency questionnaire (FFQ) to assess long-term dietary patterns. The collected data were analyzed using specialized software called Diet Cal (Kaur 2017). A dietary diversity score (DDS) was calculated for each participant based on the consumption of various food groups over the assessment period, serving as a robust proxy for nutrient adequacy and phytochemical richness.

2.4 Anthropometric and body composition assessments

Anthropometric measurements were conducted using calibrated, high-precision equipment to minimize measurement error. Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer. Body weight was recorded to the nearest 0.1 kg using a calibrated digital scale (Jelliffe, 1966). From these primary measurements, the body mass index (BMI) was computed using the formula provided by the WHO expert consultation (2004) in kg/m². Waist and hip circumferences were measured at anatomically standardized sites to calculate the waist-hip ratio, a key indicator of central adiposity. To gain deeper insights into body composition, a multi-frequency bioelectrical impedance analysis (BIA) using the TANITA body composition analyzer (BC-420MA) was employed to estimate body fat percentage and, critically, the visceral fat rating, which provides a quantitative measure of metabolically active adipose tissue surrounding the internal organs.

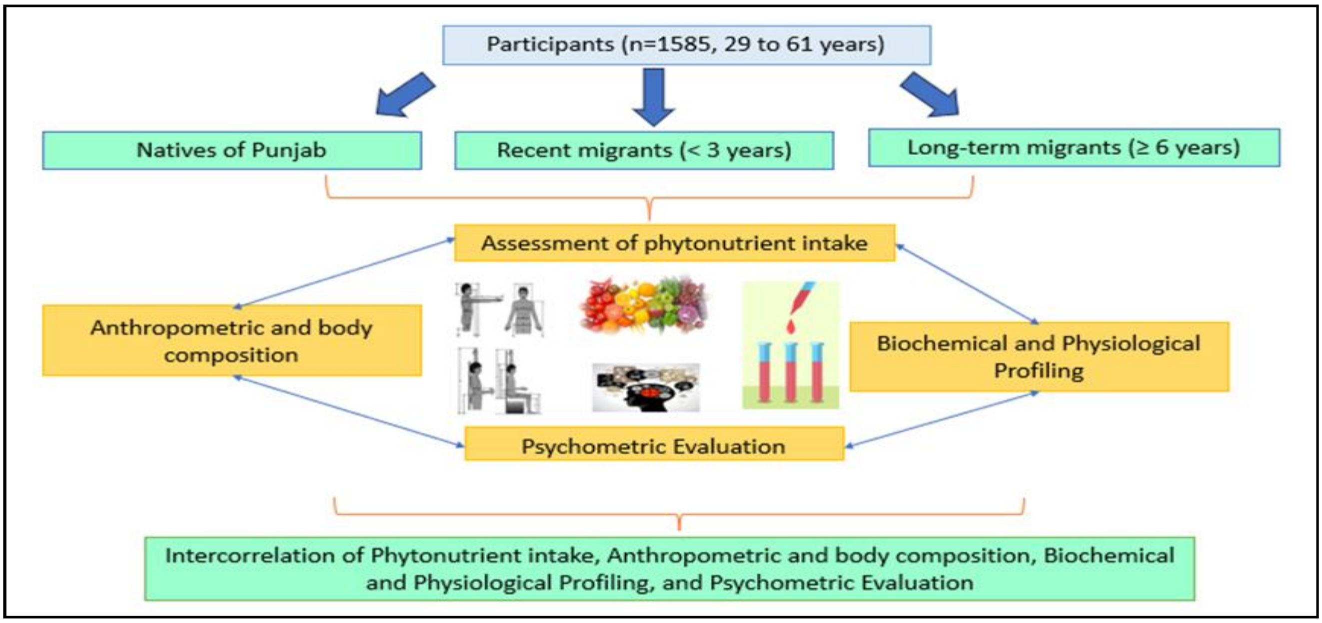

Figure 1: **Study design showing participant classification and the intercorrelation of phytonutrient intake with anthropometric, biochemical, physiological, and psychometric parameters.**

2.5 Biochemical and physiological

Profiling following a mandatory 8h overnight fast, venous blood samples were collected from each participant by certified phlebotomists. All samples were processed and analyzed at a NABL-accredited central laboratory using automated analyzers and standardized enzymatic methods. The comprehensive biochemical profile includes fasting blood glucose. Arterial blood pressure was measured in a seated position after a 5 min rest period using a calibrated sphygmomanometer, with the average of three consecutive readings being recorded.

2.6 Psychometric evaluation

A suite of validated and culturally adapted psychometric ADSS scale was used to assess the psychological health of the participants (Bhatnagar and Singh, 2016). The scale includes standardized scales for quantifying symptoms of anxiety, depression, and perceived stress.

2.7 Statistical analysis

All data were entered into a secure electronic database and subjected to rigorous statistical analysis using Statistical Packagefor the Social Sciences (SPSS) (version 25.0). Continuous variables were expressed as mean ± standard deviation, while categorical data were presented as frequencies and percentages. The analysis of variance (ANOVA) followed by post hoc tests was used to compare means across the three residential groups. A p-value of less than 0.05 was considered statistically significant, and pearson correlation coefficients (two-tailed; $p<0.05$) were used to find intercorrelations.

3. Results

3.1 Participant stratification

Of the 1,589 enrolled adults (aged 29 to 61 years), stratification by duration of residence resulted in three groups: natives (n=858), recent migrants (<3 years; n=133), and long-term migrants ($\geq$6 years; n=598). This classification facilitated a direct comparison of phytonutrient intake, anthropometric, biochemical, and psychometric parameters among groups with differing durations of exposure to the local dietary lifestyle environment.

3.2 Phytonutrient intake patterns

An analysis of phytonutrient consumption patterns is summarized in Table 1. Statistical analysis revealed no significant variations among native residents, recent migrants (<3 years), and long-term migrants ($\geq$6 years) regarding their intake of total dietary fiber, ascorbic acid, vitamin D,and omega-3/omega-6 fatty acids ($p>0.05$). While β-carotene consumption showed slight variations (F =2.711; $p=0.067$), these differences were not statistically significant. Native residents demonstrated the highest average α-carotene intake,1201.45 ± 395.05 µg,followed by long-term migrants 1176.75 ± 382.73 µg and recent migrants 1120.78 ± 376.74 µg.The dietary diversity score (DDS) exhibited significant differences between groups (F=5.251; $p=0.005$). Recent migrants demonstrated the highest dietary diversity (9.62 ± 1.45, followed by long-term migrants 9.23 ± 1.40 and native residents 9.20 ± 1.38. This elevated DDS among recent migrants suggests a more varied dietary pattern, potentially offering enhanced phytonutrient exposure despite similar macro and micronutrient profiles across all groups.

Table 1: Phytonutrient intake and dietary diversity score of native and migrants (n = 1585)

Parameters (per 100 g)	Native	<3 years	$\geq$ 6 years	Fvalue	p value
Total dietary fiber (g)	$12.10^{a} \pm 2.26$	$12.02^{a} \pm 2.25$	$11.97^{a} \pm 2.33$	0.528	0.590
Total ascorbic acid (mg)	$24.56^{a} \pm 11.67$	$24.55^{a} \pm 10.94$	$23.85^{a} \pm 11.99$	0.680	0.507
β-Carotene (µg)	$1201.45^{b} \pm 395.05$	$1120.78^{a} \pm 376.74$	$1176.75^{ab} \pm 382.73$	2.711	0.067
Vitamin D (mg)	$5.12^{a} \pm 2.88$	$4.73^{a} \pm 2.88$	$4.91^{a} \pm 2.90$	1.601	0.202
Omega 3 (g)	$1.57^{a} \pm 0.91$	$1.52^{a} \pm 0.84$	$1.55^{a} \pm 0.93$	0.247	0.781
Omega 6 (g)	$14.73^{a} \pm 8.61$	$14.83^{a} \pm 8.39$	$14.46^{a} \pm 8.52$	0.215	0.807
Dietary diversity score	$9.20^{a} \pm 1.38$	$9.62^{b} \pm 1.45$	$9.23^{a} \pm 1.40$	5.251	0.005^{*}

Note: Means with different superscript letters (a, b, ab, c, and bc) within a row are significantly different; *indicates statistical significance at $p<0.05$ level.

The data indicate consistent phytonutrient consumption across all populations,with only minor variations in β-carotene intake likely attributable to different food choices. The notable distinction in dietary diversity highlights its significance in influencing both phytochemical exposure and overall nutritional quality.

3.3 Anthropometric and body composition findings

Table 2 presents anthropometric and body composition data. A statistically significant difference in age was observed among groups ($p<0.001$), with natives being older (48.20 ± 8.29 years) than recent migrants (43.48 ± 9.14 years) and long-term migrants (44.32 ± 9.15 years). BMI differences were pronounced: natives showed the highest mean BMI 27.55 ± 4.76 kg/m², whereas recent migrants had the lowest 24.93 ± 3.19 kg/m² and long-term migrants intermediate 25.77 ± 4.84 kg/m² ($p<0.001$). Measures of central adiposity, waist circumference, and hip circumference were similarly highest in natives 97.74 ± 9.96 cm and 105.39 ± 11.81 cm, respectively with highly significant group differences ($p<0.001$). The waist-hip ratio also varied ($p<0.001$) with natives at 0.93 ± 0.05, recent migrants at 0.93 ± 0.04, and long-term migrants at 0.92 ± 0.05.

The average body fat percentage for natives was 33.73 ± 7.92% for recent migrants it was 31.35 ± 6.65% and for long-term migrants it was 33.33 ± 6.69% (p = 0.03). Notably, the visceral fat rating was significantly lower in both migrant groups (approximately 8.7) and higher in natives 11.68 ± 4.91 ($p<0.001$). Therefore, compositional measures verify that natives are more adipose and have a higher visceral fat burden than migrants, which may be the effect of dietary choices, as natives are living in an obesogenic environment and consuming more calorie-dense food than migrants.

Table 2: Anthropometric and body composition of native and migrant (n=1585)

Parameters	Native	<3 years	≥ 6 years	F value	*p* value
Age (years)	$48.20^{b} \pm 8.29$	$43.48^{a} \pm 9.14$	$44.32^{a} \pm 9.15$	42.918	0.00*
BMI (kg/m²)	$27.55^{c} \pm 4.76$	$24.93^{a} \pm 3.19$	$25.77^{b} \pm 4.84$	35.229	0.00*
Waist circumference (cm)	$97.74^{b} \pm 9.96$	$92.55^{a} \pm 10.04$	$92.52^{a} \pm 11.16$	49.256	0.00*
Hip circumference (cm)	$105.39^{b} \pm 11.81$	$99.04^{a} \pm 9.01$	$100.85^{a} \pm 10.86$	38.381	0.00*
Waist-hip ratio	$0.93^{b} \pm 0.05$	$0.93^{b} \pm 0.05$	$0.92^{a} \pm 0.05$	12.179	0.00*
Fat (%)	$33.73^{a} \pm 7.92$	$31.35^{a} \pm 6.65$	$33.33^{a} \pm 6.69$	3.474	0.03*
Bone mass (kg)	$2.78^{b} \pm 0.49$	$2.42^{a} \pm 0.46$	$2.46^{a} \pm 0.48$	91.773	0.00*
Total body water (%)	$47.29^{a} \pm 4.39$	$47.97^{a} \pm 3.90$	$47.24^{a} \pm 4.27$	1.641	0.19
Muscle mass (kg)	$46.93^{b} \pm 10.19$	$40.86^{a} \pm 8.14$	$40.88^{a} \pm 8.55$	80.854	0.00*
Visceral fat rating (%)	$11.68^{b} \pm 4.91$	$8.78^{a} \pm 4.26$	$8.69^{a} \pm 4.12$	83.384	0.00*

Note: Means with different superscript letters (a, b, ab, c, and bc) within a row are significantly different; * indicates statistical significance at $p<0.05$ level.

3.4 Biochemical and physiological markers

Figure2 indicates that there was a slight intergroup difference in fasting blood glucose levels ($p=0.06$) with slightly higher mean values among natives and the overall population had 103.85 ± 44.12 mg/dl. Stronger variations in blood pressure were found: natives' mean systolic pressure was significantly higher (121.78 ± 16.48 mmHg) than that of recent (116.02 ± 14.65 mmHg) and long-term migrants (117.39 ± 14.98 mmHg) migrants ($p<0.001$). Additionally, diastolic pressure varied significantly ($p=0.02$) with migrant groups averaging approximately 76 mmHg and natives 79.70 ± 10.88 mmHg (Figure 3). These physiological indicators support the anthropometric results, showing that natives' higher levels of adiposity are correlated with higher blood pressure measurements and their dietary habits.

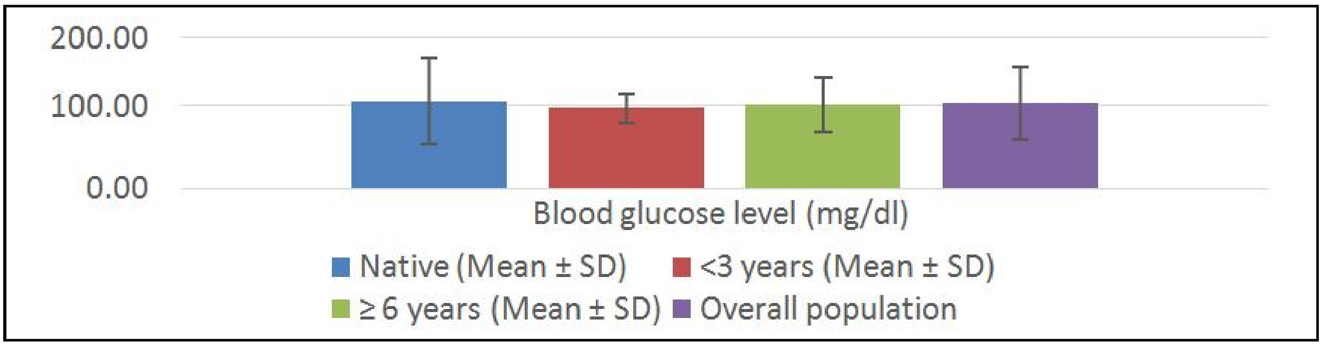

Figure 2: Mean blood glucose levels (mg/dl) across native, recent migrants (<3 years), long-term migrants (≥6 years)and the overall population.

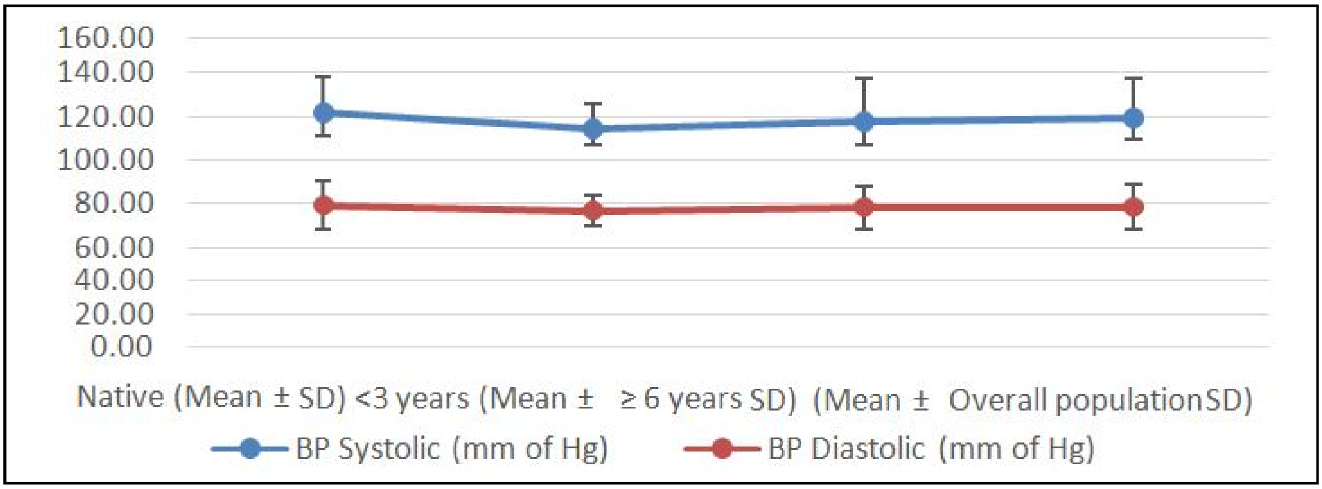

Figure 3: Mean systolic and diastolic blood pressure (mmHg) among native, recent migrants (<3 years), long-term migrants (≥6 years) and the overall population.

Table 3: Psychological factors of native and migrant (n = 1585)

Parameters	Native	<3 years	≥ 6 years	F value	*p* value
Anxiety raw score	$4.93^{b}\pm 4.66$	$4.14^{a}\pm 4.33$	$4.10^{a}\pm 4.77$	6.087	0.002*
Depression raw score	$2.01^{a}\pm 3.33$	$1.47^{a}\pm 2.83$	$1.76^{a}\pm 3.19$	2.181	0.113
Stress raw score	$1.99^{a}\pm 3.35$	$1.50^{a}\pm 2.99$	$1.73^{a}\pm 3.22$	1.914	0.148

Note: Means with different superscript letters (a, b, ab, c, and bc) within a row are significantly different; * indicates statistical significance at $p<0.05$ level.

3.5 Psychometric scores

The distribution of anxiety, depressionand stress levels among native residents and migrant populations is presented in Table 3 and Figures 4, 5 and 6 with migrants categorized as recent (less than 3 years) or long-term (more than 6 years).

Analysis revealed significant differences in anxiety levels between groups (F= 6.087; p=0.002). Native residents demonstrated higher mean anxiety scores, 4.93 ± 4.66, compared to both recent migrants, 4.14 ± 4.33, and long-term migrants, 4.10 ± 4.77. The distribution of anxiety levels showed that native residents had the highest proportion of below-average anxiety, 43.47%, while long-term migrants exhibited predominantly low anxiety levels, 37.96%. Notably, high or extremely high anxiety levels were rare across all groups, 1 to 8%. These results indicate enhanced psychological adjustment among migrant populations, particularly those with longer residency.

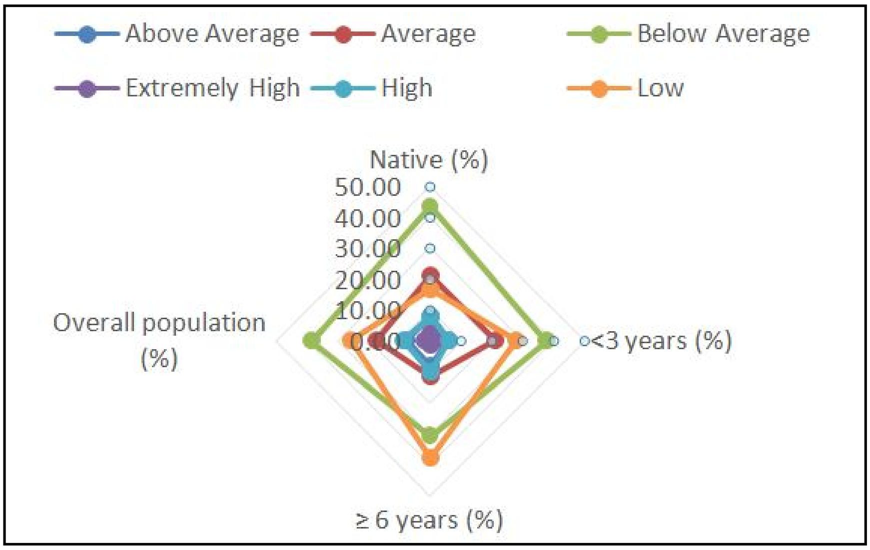

Figure 4: Percentage distribution of anxiety levels among native, recent migrants (<3 years), long term migrants (≥ 6 years) and the overall population.

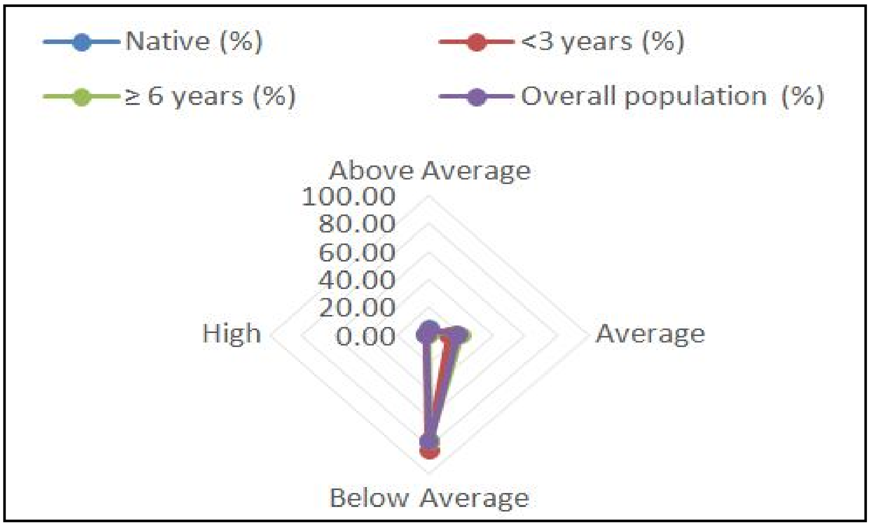

Figure 5: Percentage distribution of depression levels among native, recent migrants (<3 years), long-term migrants (≥ 6 years)and the overall population.

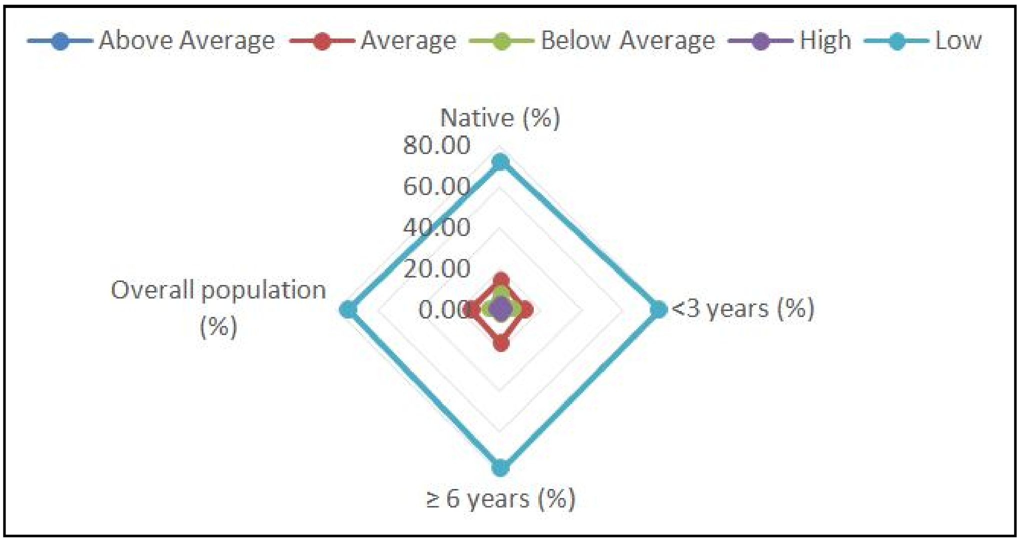

Figure 6: Percentage distribution of stress levels among native, recent migrants (<3 years), long-term migrants (≥6 years) and the overall population.

Depression scores remained consistent across all groups with no statistically significant differences (F=2.181; p=0.113). The vast majority of participants, 76 to 83% reported below-average depression levels,and only a small percentage,1 to 4% indicated high or above-average symptoms, suggesting minimal depressive burden across the study population. Stress levels also showed no significant variation between groups (F = 1.914; p=0.148). The data revealed predominantly low stress levels, 72 to 78% across all populations, with high stress being exceptionally rare 2% or less.

3.6 Correlation pattern between dietary phytonutrients and body composition indicators

The intercorrelation analysis between phytonutrients and body composition indicators reveals important relationships affecting health outcomes in Punjab's native and migrant populations. Statistical analysis demonstrates that increased dietary diversity correlates significantly with improved body composition measurements. The dietary diversity score (DDS) shows notable negative correlations with key metrics: BMI (r = –0.074; p<0.01), waist circumference (r = –0.077; p<0.01) and hip circumference (r = –0.068; p<0.01). These findings indicate that participants who consume more varied diets typically maintain lower body fat levels. Furthermore, DDS correlates positively with total body water percentage (r = 0.088; p<0.01), suggesting that dietary variety promotes healthier body composition. The analysis of specific nutrients reveals varying relationships with body composition. While total dietary fiber and vitamin C show mild negative correlations with body fat measurements and slight positive correlations with body water content these associations lack statistical significance. β-carotene demonstrates a significant positive correlation with waist-hip ratio (r = 0.057; p<0.05) suggesting its influence on fat distribution patterns. Vitamin D exhibits weak negative correlations with adiposity indicators, consistent with research linking vitamin D deficiency to increased body fatthough these findings remain statistically insignificant in this study. Omega-3 fatty acids display modest positive correlations with waist-hip ratio, bone massand muscle mass, indicating potential benefits for lean body composition. Conversely, omega-6 fatty acids show minimal correlation with these measurements. The findings emphasize that dietary diversity emerges as a more reliable indicator of healthy body composition than individual nutrient intake across both population groups. This research reinforces the fundamental importance of maintaining a varied, balanced diet to achieve optimal health outcomes across different populations (Table 4).

Table 4: Correlation between phytonutrient intake and anthropometric or body composition indicators among native and migrant populations of Punjab, demonstrating significant inverse associations of dietary diversity with adiposity measures.

Parameters (per 100 g)	BMI	Waist circumference	Hip circumference	Waist hip ratio	Fat (%)	Bone mass	Total body water (%)	Muscle mass	Visceral fat rating
Total dietary fiber (g)	-0.032	-0.021	-0.021	0.004	0.034	0.008	0.047	0.005	0.006
Total ascorbic acid (mg)	-0.013	-0.003	0.000	-0.007	-0.005	-0.005	0.046	0.006	-0.023
β-Carotene (µg)	0.020	0.028	-0.002	0.057*	-0.029	0.024	0.006	0.018	0.028
Vitamin D (mg)	-0.011	-0.009	-0.010	0.002	-0.019	0.012	-0.005	0.002	-0.018
Omega 3 (g)	-0.003	0.017	-0.002	0.033	-0.023	0.028	0.029	0.036	0.018
Omega 6 (g)	0.005	-0.013	-0.011	-0.004	-0.008	-0.001	-0.015	-0.006	-0.001
Dietary diversity score	-0.074**	-0.077**	-0.068**	-0.026	-0.040	-0.025	0.088**	0.021	0.007

** Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed).

3.7 Associations between phytonutrient intake and metabolic and psychological parameters

The analysis examines the relationships between key phytonutrients and various health metrics, including blood glucose, blood pressure and psychological indicators across Punjab's native and migrant populations. The data reveals complex patterns of correlation with significance levels marked at *$p<0.05$ and **$p<0.01$. Dietary fiber shows a weak but significant positive correlation with blood glucose (r = 0.073; $p<0.01$) potentially indicating compensatory dietary adjustments rather than causation. The data show no meaningful correlations between fiber intake and cardiovascular or psychological parameters. Vitamin C (ascorbic acid) demonstrates subtle negative correlations across most health metrics though none reach statistical significance. This pattern aligns with vitamin C known antioxidant properties but lacks strong statistical support in this dataset. Notable findings emerge with β-carotene, which shows significant positive correlations with psychological measures: anxiety (r = 0.062; $p<0.05$), depression (r = 0.063; $p<0.05$) and stress (r = 0.069; $p<0.01$). These associations might reflect stress induced dietary changes rather than β-carotene's direct psychological impact. Vitamin D correlations remain statistically insignificant, showing minor positive associations with psychological metrics and a slight negative relationship with blood glucose. While these patterns align with vitamin D known roles in metabolism and mood regulation the correlations are minimal. Both omega-3 and omega-6 fatty acids exhibit weak positive correlations with metabolic and psychological parametersthough none achieve statistical significance. The dietary diversity score (DDS) similarly shows minimal positive correlations with blood glucose and psychological measures. The most compelling finding centers on β-carotene's consistent positive correlations with psychological parameters. This relationship may reflect population specific dietary patterns and stress responses, particularly within the context of migration-relatedchallenges. Other nutrients demonstrate limited or insignificant associations suggesting complex interactions between dietary intake and health outcomes in this population (Table 5).

Table 5: Intercorrelation between phytonutrient intake and clinical/psychometric indicators among native and migrant populations of Punjab

Parameters (per 100 g)	Blood glucose level	BP systolic	BP Diastolic	Anxiety	Depression	Stress
Total dietary fiber (g)	0.073**	-0.028	-0.024	0.007	0.017	0.009
Total ascorbic acid (mg)	-0.014	-0.007	-0.016	-0.015	-0.029	-0.023
β-Carotene (μg)	0.013	0.019	0.014	0.062*	0.063*	0.069**
Vitamin D (mg)	-0.040	0.013	0.007	0.004	0.026	0.028
Omega 3 (g)	0.010	0.016	0.011	0.032	-0.005	0.014
Omega 6 (g)	0.031	-0.024	0.006	0.012	0.004	0.008
Dietary diversity score	0.036	0.001	0.004	0.024	0.006	0.006

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed).

4. Discussion

The present investigation explored the complex interrelationship between phytonutrient intake, dietary diversity, anthropometric, biochemical, physiological and psychometric parameters among native and migrant populations of Punjab, revealing distinct patterns in metabolic and psychological health associated with dietary adaptation. Although, total phytonutrient intake, including dietary fibre, ascorbic acid, β-carotene, vitamin D and omega-3 and omega-6 fatty acids did not differ significantly across groups ($p>0.05$), dietary diversity showed a highly significant variation (F = 5.251; $p=0.005$). Recent migrants exhibited the highest dietary diversity score 9.62 ± 1.45 compared to long-term migrants 9.23 ± 1.40 and natives 9.20 ± 1.38, suggesting that shorter exposure to the urban dietary environment preserved more traditional, plant-based food habits. Such diversity ensures greater intake of phytochemical-rich foods, which contribute bioactive compounds with antioxidant, anti-inflammatory and gene-modulatory properties that help maintain metabolic balance (Liu, 2013; Rudrapal *et al.,* 2022; Panche *et al.,* 2016). In contrast native populations due to prolonged exposure to calorie-dense, nutrient-poor diets, displayed significantly higher adiposity levels reflected in elevated mean BMI 27.55 ± 4.76 kg/m², waist circumference 97.74 ± 9.96 cm, hip circumference 105.39 ± 11.81 cm and visceral fat rating 11.68 ± 4.91 compared to recent 24.93 ± 3.19 kg/m²; 92.55 ± 10.04 cm; 99.04 ± 9.01 cm; 8.78 ± 4.26 and long-term migrants 25.77 ± 4.84 kg/m²; 92.52 ± 11.16 cm; 100.85 ± 10.86 cm; 8.69 ± 4.12 with all $p<0.001$. These findings align with previous research linking reduced phytonutrient intake and urban dietary acculturation to increased central adiposity and metabolic disease risk (Alidu and Grunfeld, 2018; Misra *et al.,* 2011; Schulze *et al.,* 2018). Correlation analysis confirmed that dietary diversity was inversely associated with BMI (r = –0.074; $p<0.01$), waist circumference (r = –0.077; $p<0.01$) and hip circumference (r = –0.068; $p<0.01$), while positively correlated with total body water (r = 0.088; $p<0.01$), indicating that a diverse diet supports leaner body composition and healthier fluid balance. Similar associations between diversified plant-based diets and lower obesity prevalence have been documented in global and Indian populations (Ganpule *et al.,* 2023; WHO, 2021).

The physiological profile also reflected this pattern with natives exhibiting significantly higher systolic 121.78 ± 16.48 mmHg and diastolic 79.70 ± 10.88 mmHg blood pressures than recent 116.02 ± 14.65 mmHg; 76.09 ± 10.26 mmHg and long-term migrants 117.39 ± 14.98 mmHg; 76.35 ± 10.12 mmHg $p<0.001$ and $p=0.02$, respectively, suggesting an elevated cardiovascular load related to adiposity and reduced nutrient diversity. This is in agreement with prior findings that link hypertension and vascular dysfunction to poor dietary quality and central obesity (Sebastian *et al.,* 2022). Psychometric assessments revealed a similar trend, with anxiety scores significantly higher among natives (4.93 ± 4.66; $p=0.002$) compared to migrants, while depression ($p=0.113$) and stress ($p=0.148$) remained statistically similar. The elevated anxiety among natives may result from combined metabolic, environmental, and psychosocial stressors, compounded by nutritional inadequacies. Prior studies support that phytonutrient-rich diets, particularly those abundant in flavonoids and carotenoids, improve psychological stability by regulating neurotransmitter synthesis, enhancing cerebral blood flow, and reducing oxidative neural stress (Lassaleet *al.,* 2019; Grajek *et al.,* 2022; Nicolucci *et al.,* 2024). Interestingly, β-carotene showed weak positive correlations with anxiety (r = 0.062; p<0.05) and stress (r = 0.069; p<0.01), potentially reflecting stress-related dietary responses rather than direct causation. Collectively, the data demonstrate that dietary diversity exerts a stronger influence on metabolic and mental health than individual phytonutrient consumption. These findings align with contemporary models of nutritional psychiatry and chronic disease prevention, which highlight that multiple phytonutrients act synergistically to modulate oxidative stress, inflammatory signaling, and gut-brain communication (Rudrapal *et al.,* 2022; Panche *et al.,* 2016; Sun *et al.,* 2023). Therefore, the evidence from this study underscores that maintaining a phytonutrient-rich, diverse diet is critical for sustaining metabolic stability and psychological resilience. Natives of Punjab, due to their longer exposure to urban dietary patterns, exhibit increased vulnerability to obesity, hypertension, and anxiety, whereas migrant populations, particularly recent migrants,benefit from more balanced, traditional diets. Promoting culturally grounded dietary diversity through inclusion of fruits, vegetables, legumes, millets, and oilseeds represents a sustainable public-health strategy to counteract the dual burden of metabolic and psychological disorders in populations undergoing dietary transition in Punjab.

5. Conclusion

The present study examined the intercorrelation of phytonutrient intake with anthropometric, biochemical, physiological and psychometric indicators among 1,585 adults belonging to native and migrant populations of Punjab. The findings revealed that while overall phytonutrient intakecomprising total dietary fiber, ascorbic acid, β-carotene, vitamin D, and omega fatty acids,was comparable across all groups (p>0.05), dietary diversity showed significant variation (F=5.251; p=0.005). Recent migrants demonstrated the highest dietary diversity score, 9.62 ± 1.45, followed by long-term migrants, 9.23 ± 1.40, and natives, 9.20 ± 1.38, indicating that newer migrants maintained more varied and phytochemical-rich diets. Anthropometric and body composition assessments highlighted that natives exhibited significantly higher body mass index 27.55 ± 4.76 kg/m², waist circumference 97.74 ± 9.96 cm, hip circumference 105.39 ± 11.81 cm and visceral fat rating 11.68 ± 4.91 compared to migrants (p<0.001), suggesting a greater predisposition to central obesity and metabolic risk. Correspondingly, the physiological findings showed that natives had higher mean systolic 121.78 ± 16.48 mmHg and diastolic 79.70 ± 10.88 mmHg blood pressures compared to recent and long-term migrants (p<0.001 and p=0.02, respectively), reinforcing the link between adiposity and cardiovascular strain. Psychometric evaluations revealed that natives had significantly higher anxiety scores (4.93 ± 4.66; p=0.002) than migrant groups, although depression and stress levels did not differ notably (p>0.05). Correlation analyses further indicated that dietary diversity was inversely associated with body mass index (r = –0.074; p<0.01), waist circumference (r = –0.077; p<0.01) and hip circumference (r = –0.068; p<0.01), while showing a positive correlation with total body water (r = 0.088; p<0.01), emphasizing that a more varied diet contributes to healthier body composition. In contrast, â-carotene exhibited mild positive correlations with anxiety (r = 0.062; p<0.05) and stress (r = 0.069; p<0.01), which may reflect stress-induced dietary behaviors rather than causal effects. Finally, the study concludes that dietary diversity, rather than the consumption of individual phytonutrients, plays a more significant role in maintaining metabolic balance and psychological well-being. The results suggest that native populations, due to prolonged exposure to calorie-dense and less diverse diets, are at higher risk of obesity, hypertension and anxiety. Therefore, promoting dietary diversity through the inclusion of phytochemical-rich foods such as fruits, vegetables, legumes, whole grains and oilseeds could serve as an effective, sustainable strategy to improve both metabolic and mental health among populations exposed to modern dietary transitions in Punjab.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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